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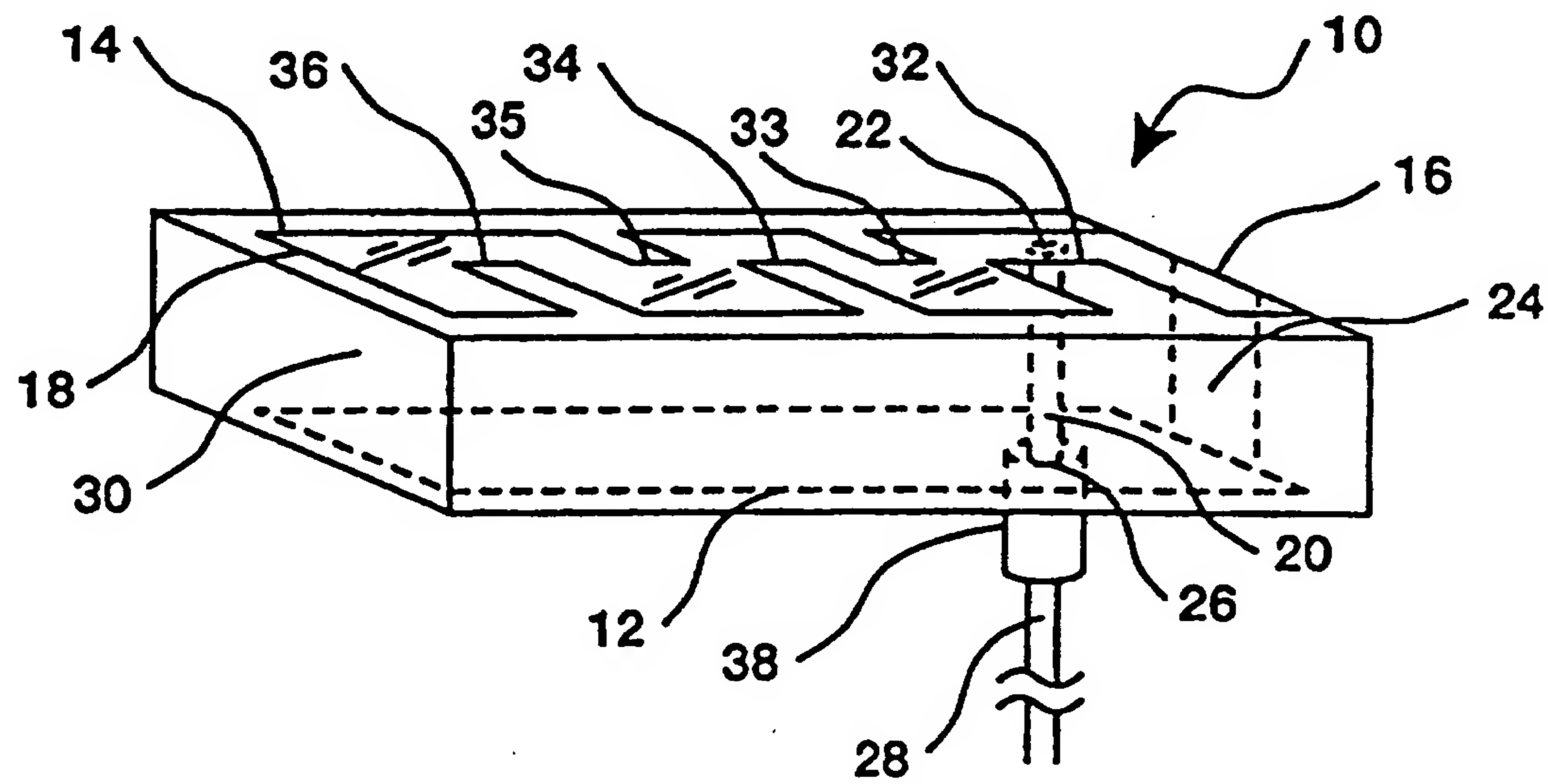
(54) Title: MEANDERING INVERTED-F ANTENNA

(57) Abstract



A planar meandering inverted-F antenna is provided, which is in one embodiment a broadband omnidirectional radiator and in another embodiment a narrow band omnidirectional radiator. The meandering inverted-F is a planar radiating structure having alternating cutouts along a longitudinal dimension of a planar radiating element or patch which is parallel to a nearly coextensive ground plane. In all cases the antenna structure as a whole has the advantage of an efficient omnidirectional radiation pattern from a structure which has a maximum dimension of less than 1/5 of the wavelength of the operating frequency and preferably as small as 1/10 of the wavelength of the operating frequency. Factors which impact frequency and bandwidth include: meandering patch length, vertical element (also called "post") height and width, and permittivity of the dielectric spacer between the meandering patch and the ground plane. The structure is easily manufactured due to its simple design and absence of requirements of exotic materials or multidimensional shaping processes. Three embodiments are discussed: an air-dielectric version for broadband and low cost applications, a thick solid-dielectric version having broadband applications, and a thin solid-dielectric version having narrow band applications.

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MEANDERING INVERTED-F ANTENNA

BACKGROUND OF THE INVENTION

This invention relates to antennas, and more particularly to a new type of antenna suitable for UHF and microwave applications.

With the recent advances of mobile communications, there has been tremendous interest in development of small and low profile antennas for the further miniaturization of mobile telephone sets. Goals include small size, low profile, low cost and ease of manufacturing. The frequencies of interest include 900 MHz band antennas for applications in cellular handheld phones such as for GSM (890, 935 MHz), indoor cordless telephones such as the European CT1+(886, 931 MHz) and 1.9 GHz band antennas for applications in the 1.89 GHz Digital European Cordless Telecommunications (DECT), and the 1.8 GHz European future Personal Communication Services, namely the DCS1800 systems. These systems have their own requirements in antenna characteristics, such as resonant frequency, bandwidth,

A review of prior art found a variety of directional antennas based on three-dimensional designs, such as helical antennas.

Existing antennas used in mobile phones include the most common whip antennas (monopole), microstrip patch antennas and planar inverted-F antennas. A mobile telephone with a half wavelength or quarter wavelength whip antenna (monopole) is long known as a hindrance to user. The whip is easily broken and is always a hazard as it can poke the eyes of the user.

Microstrip patch antennas, as disclosed in J.Q. Howell, "Microstrip Antennas," IEEE Trans. Antenna and Propagation, Vol. AP-23, January 1975, pp. 90-93, and planar inverted-F antennas, as disclosed in J.R. James, K. Fujitomo, A. Henderson, and K. Hirasawa, Small Antennas, Research Studies Press, 1987, pp. 116-151, are typical low-profile antennas. Although the microstrip patch antenna has the shortcoming of

narrow bandwidth and low efficiency, its advantages of low-profile, small size and light weight are attractive properties. The planar inverted-F antenna has already been used in mobile telephone handsets and is one of the most promising designs, as suggested by K. Qassim, "Inverted-F Antenna for Portable Handsets",IEE Colloquium on Microwave Filters and Antennas for Personal Communication Systems", pp. 3/1 - 3/6, Feb. 1994, London, UK. However, both microstrip patch and planar inverted-F antennas are still too large to fit into the newer generation of miniature mobile phone handsets. This is particularly problematic when modern mobile phone design calls for multiple antennas to be placed into one handset to take advantage of antenna diversity.

There are other antenna designs which are constructed with reference to a parallel ground plane. The concept of the inverted L Antenna (ILA) is simply a transmission line antenna with the center conductor bent upon its departure from the ground plane. Later variations include the inverted-F antenna (IFA), and the planar inverted-F Antenna (PIFA), wherein a feedpoint is provided at an offset from a ground point of the radiating element. Planar high impedance/choke lines are circuit board components used in RF circuits bias supplies. The lines form planar inductors with line widths which are relatively small in comparison to the wavelength of applied signals, since it is an RF choke. As such, the elements are specifically designed to suppress radiation. Parameters of the antenna that directly affect its operation are height, length, width and dielectric characteristics.

What is needed is an efficient and compact low-profile omnidirectional antenna suitable for portable applications.

SUMMARY OF THE INVENTION

According to the invention, a planar meandering inverted-F antenna is provided, which is in one embodiment a broadband omnidirectional radiator and in another embodiment a narrow band omnidirectional radiator. The meandering inverted-F is a planar radiating structure having alternating cutouts along a longitudinal dimension of a planar radiating element or patch

which is parallel to a nearly coextensive ground plane. In all cases the antenna structure as a whole has the advantage of an efficient omnidirectional radiation pattern from a structure which has a maximum dimension of less than 1/5 of the wavelength of the operating frequency and preferably as small as 1/10 of the wavelength of the operating frequency. Factors which impact frequency and bandwidth include: meandering patch length, vertical element (also called "post") height and width, and permittivity of the dielectric spacer between the meandering patch and the ground plane. The structure is easily manufactured due to its simple design and absence of requirements of exotic materials or multidimensional shaping processes. Three embodiments are discussed: an air-dielectric version, a thick solid-dielectric version having broadband applications, and a thin solid-dielectric version having narrow band applications.

The invention will be better understood upon reference to the following detailed description in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective diagrammatic representation of a meandering inverted-F antenna according to the invention.

Figure 2A and Figure 2B are respective perspective and top views of a dielectric loaded meandering inverted F antenna according to the invention.

Figure 3A and Figure 3B are respective perspective and top views of two different air loaded meandering inverted F antenna according to the invention.

Figure 4A, Figure 4B and Figure 4C are respective top, bottom and end views of a microstrip dielectric loaded meandering inverted F antenna according to the invention.

Figure 5A and Figure 5B are the input impedance and VSWR diagrams of the dielectric loaded MIF antenna.

Figure 6A and Figure 6B are the input impedance and VSWR diagrams of a 1.9 GHz air loaded MIF antenna.

Figure 7A and Figure 7B are the input impedance and VSWR diagrams of a microstrip MIF antenna.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to Figure 1, there is shown a perspective diagrammatic representation of a meandering inverted-F antenna 10 according to the invention. The antenna 10 has the following components and features: a ground plane element 12, a planar radiating element or meandering patch 14 as hereinafter explained, the patch 14 being substantially coextensive with the ground plane element 12 and disposed juxtaposed to and parallel with the ground plane element 12. The patch 14 is the primary radiating element. It has a first edge 16 and a second edge 18, with the second edge 18 opposing the first edge 16. The distance between the first edge 16 and the second edge 18 is a fraction of the wavelength at the center or operating frequency of the antenna 10. The length may be greater or less than the width, but in the preferred embodiment it has been found that a structure where the ratio of length to width is about 2:1 to 3:1 is satisfactory.

The antenna 10 further includes a hot feed element 20 coupled to a feed point 22 somewhere on the patch 14, depending upon the desired input impedance, and a ground post element 24 coupling the patch 14 to the ground plane element 12 adjacent the first edge 16. The hot feed element 20 is for example from a wire conductor 28 of a coaxial feed through a hole 26 in the ground plane element 12. The antenna 10 is further characterized by a dielectric planar element 30 separating the ground plane element 12 and the patch 14.

According to the invention, the patch 14 defines a planar meandering electrically conductive pattern for radiating r.f. energy formed by alternating lateral cutouts 32-36 between the first edge 16 and the second edge 18.

The antenna is preferably fed with a microstrip flange launcher 38, which is a coaxial cable connector, with its center element connected to the conductor 28. For the dielectric loaded embodiment, for example, the center pin of the launcher 38, is soldered to a metallic strip which is then attached to the meandering patch. In a thinner microstrip version (Fig. 4A, B, C), the center pin of the launcher 38 is directly soldered to the microstrip patch 14. Feed matching is

not a problem, so designs can achieve a VSWR below 1.02 without much difficulty.

Several specific designs for the patch 14 in different embodiments are shown in Figures 2A, 2B, 3A, 3B and 4A, 4B. Dimensions for a 900 MHz operating frequency are shown in Fig. 2B and Fig. 4B for two different configurations. The first is 54 mm long and 15 mm wide, which is roughly 1/5 wavelength by about 1/20 wavelength. Referring to Fig. 2, a typical feed point 22 is along the edge of the first cutout 32, such as at the base of the cutout 32. The patch 14 is preferable a rectangular structure, although it could be a circle or a polygon. A square or rectangular structure is believed to be most efficient, where the cutouts 32-36 are also rectangular. The cutouts alternate laterally and typically terminate along or near a common longitudinal axis 42 or slightly beyond the common longitudinal axis 42. More specifically the cutouts 32-36 extend into the planar radiating element 14 substantially to at least the common longitudinal axis 42 sufficient to force surface current in the planar radiating element 14 to flow in a meandering path between the first edge 16 and the second edge 18. The axis 42 need not be straight; it can follow a slight curve in the surface of the patch, so long as current is forced to flow through a zig-zag path.

The dimensions of the patch 14 and the cutouts 32-36 are somewhat arbitrary, but the cutouts are typically numbered between three and seven with a lateral extent of between 3/10 and 7/10 of the lateral dimension of the patch 14, and the length of the patch 14 is between 1/5 and 1/10 wavelength of the antenna's design frequency. The cutouts 32-36 each have a typical longitudinal extent of between 1/7 and 1/15 of the longitudinal dimension (length) of the patch 14, all subject to the above limitation regarding induced meandering surface current.

Referring to Fig. 2A, the patch 14 and the ground plane 12 are spaced apart by dielectric planar element 30, which is a solid having a relative permittivity of greater than 2 and less than 35, such as a reinforced polymer. A typical relative permittivity is 2.3 for a separation of 10 mm or about 1/30

wavelength. Such a design with less than 1/15 wavelength separation between its ground plane 12 and its patch 14 at its design frequency produces a relatively broadband or low Q antenna, i.e., one that has a Q of less than 30. In this case the ground post element 24 may also have a lateral dimension of between 1/5 and 1/1 of the lateral dimension of the patch 14.

Referring to Fig. 4C, there is shown a patch 14 on a ground plane 12 with a dielectric 30 therebetween. The separation (H) is typically in the range of up to 0.8 mm for a 900 MHz antenna or only about 1/400 of a wavelength. The design produces an antenna sufficiently thin to suppress a surface wave formed between the patch 14 and the ground plane 12 with a Q of well over 50, i.e. about 100. The thin dielectrically-loaded or microstrip antenna of Fig. 4A-4C is relatively smaller than a thick dielectrically-loaded antenna of Fig. 2A-2B at the same operating frequency. For example, the longitudinal dimension is only about 32 mm or about 1/10 wavelength. The particular embodiments shown have similar cutout sizes, although the microstrip version (Fig. 4A) has six cutouts at closer spacing than the thick dielectrically-loaded version (Fig. 2B). The ground post element 24 may also have a lateral dimension of between 1/5 and 1/1 of the lateral dimension of the patch 14.

Referring to Fig. 3A-3B, there are shown designs for air-loaded antennas 10 according to the invention. Its typical application is for high frequencies and low manufacturing cost. Shown in Fig. 3B is the structure for a 1.9 GHz antenna with a longitudinal dimension of about 1/5 wavelength or 35 mm. The cutout size is about 5 mm longitudinal by 8 mm lateral, and there are only three cutouts. The Q is about 20, which is very broadband for that frequency. This antenna has potential application for the U.S. Personal Communication Systems band at 1.9 GHz.

Performance of the antennas built according to the invention is noteworthy in that the radiation pattern is substantially omnidirectional, with very few and very narrow nulls.

Impedance matching is straightforward. Figures 5A and 5B show the matching and input VSWR of the dielectric loaded version (Fig. 2A-2B). The operating frequency of this example is at 855 MHz. The 2:1 VSWR bandwidth is 70.8 MHz, and the VSWR at 855 MHz is 1.005.

Figures 7A and 7B show the characteristics for a microstrip patch version matched at the same frequency for comparison. Note that the 2:1 VSWR bandwidth is a lot narrower in this case, a value of only 7.5 MHz. The VSWR is 1.02, which can be further improved with some adjustment.

Figures 6A and 6B show the matching characteristics and input VSWR of the air loaded version. The operating frequency of this example is at 1.9 GHz. The 2:1 VSWR bandwidth is 90 MHz, and the VSWR at 1.9 GHz is 1.029.

The invention has now been explained with reference to specific embodiments. Other embodiments will be apparent to those of ordinary skill in the art upon reference to the following detailed description. It is therefore not intended that this invention be limited, except as indicated by the appended claims.

WHAT IS CLAIMED IS:

1. A meandering inverted-F antenna comprising:

a ground plane element;

a planar radiating element substantially coextensive with said ground plane element disposed juxtaposed to and parallel with said ground plane element and having a first edge and a second edge, said second edge opposing said first edge;

a hot feed element coupled to a feed point of said planar radiating element;

a ground post element coupling said planar radiating element to said ground plane element along said first edge; and

a dielectric planar element separating said ground plane element and said planar radiating element;

said planar radiating element defining a planar meandering electrically conductive pattern for radiating r.f. or microwave energy, said pattern having alternating lateral cutouts between said first edge and said second edge, said lateral cutouts extending into said planar radiating element substantially to at least a common longitudinal axis sufficient to force surface current in said planar radiating element to flow in a meandering path between said first edge and said second edge.

2. The antenna according to claim 1 wherein said feed point is at a boundary of a first one of said lateral cutouts.

3. The antenna according to claim 1 wherein said planar radiating element is rectangular and wherein said cutouts are rectangular.

4. The antenna according to claim 3 wherein said cutouts have a lateral extent of between 3/10 and 7/10 of the lateral dimension of said planar radiating element.

5. The antenna according to claim 4 wherein said planar radiating element is between 1/5 and 1/10 wavelength of its design frequency and wherein said cutouts have a longitudinal extent of between 1/7 and 1/15 of the longitudinal dimension of said planar radiating element.

6. The antenna according to claim 5 having between three cutouts and seven cutouts.

7. The antenna according to claim 3 wherein said dielectric planar element is air.

8. The antenna according to claim 3 wherein said dielectric planar element is a solid having a relative permittivity of greater than 2 and less than 35.

9. The antenna according to claim 8 wherein said dielectric planar element is sufficiently thin such that the antenna has a high Q.

10. The antenna according to claim 3 wherein separation between said planar radiating element and said ground plane element is greater than 1/150 wavelength at its design frequency, such that the antenna has a low Q.

11. The antenna according to claim 1 wherein said ground post element has a lateral dimension of between 1/5 and 1/1 of the lateral dimension of said planar radiating element.

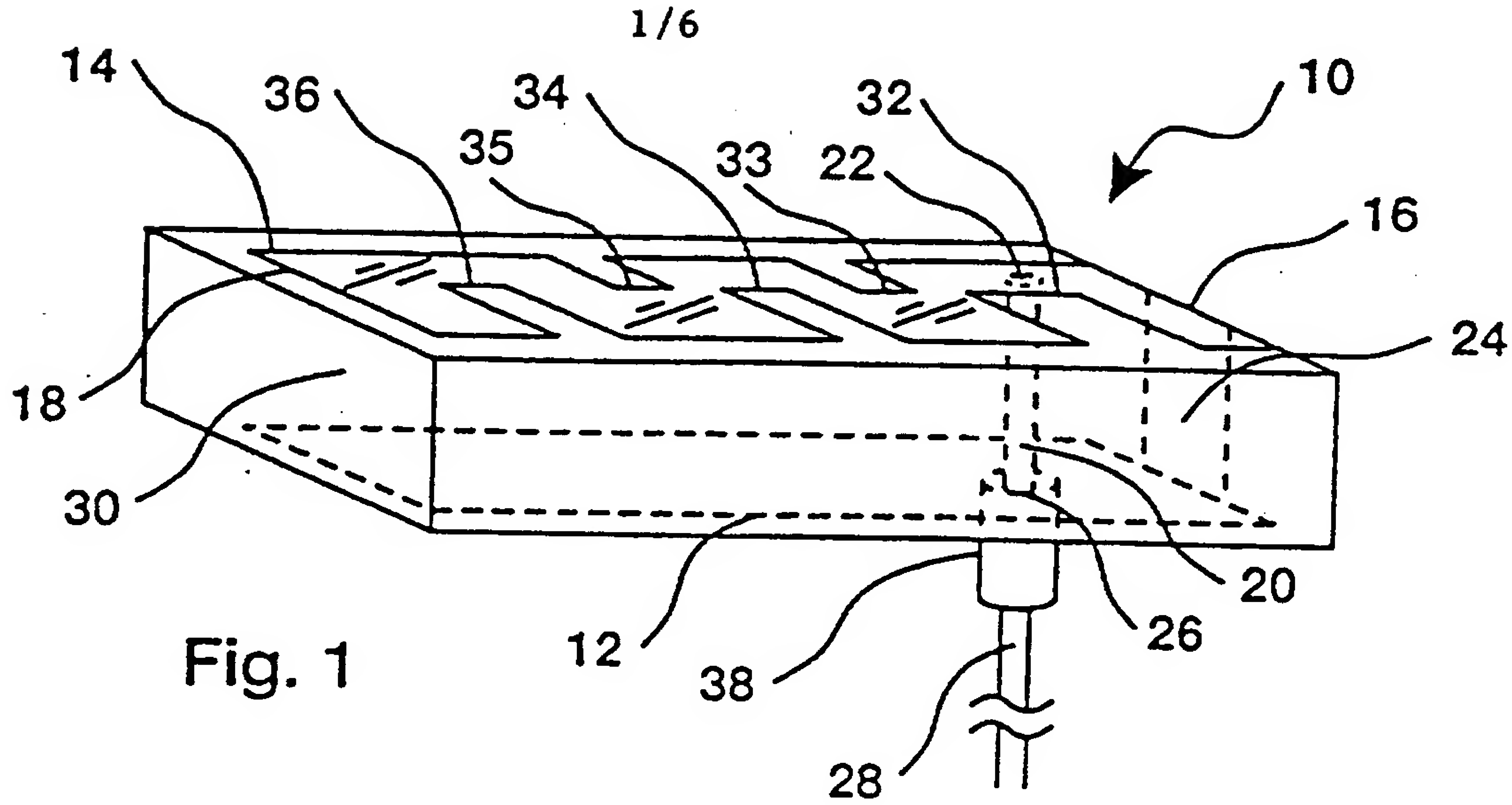

Fig. 1

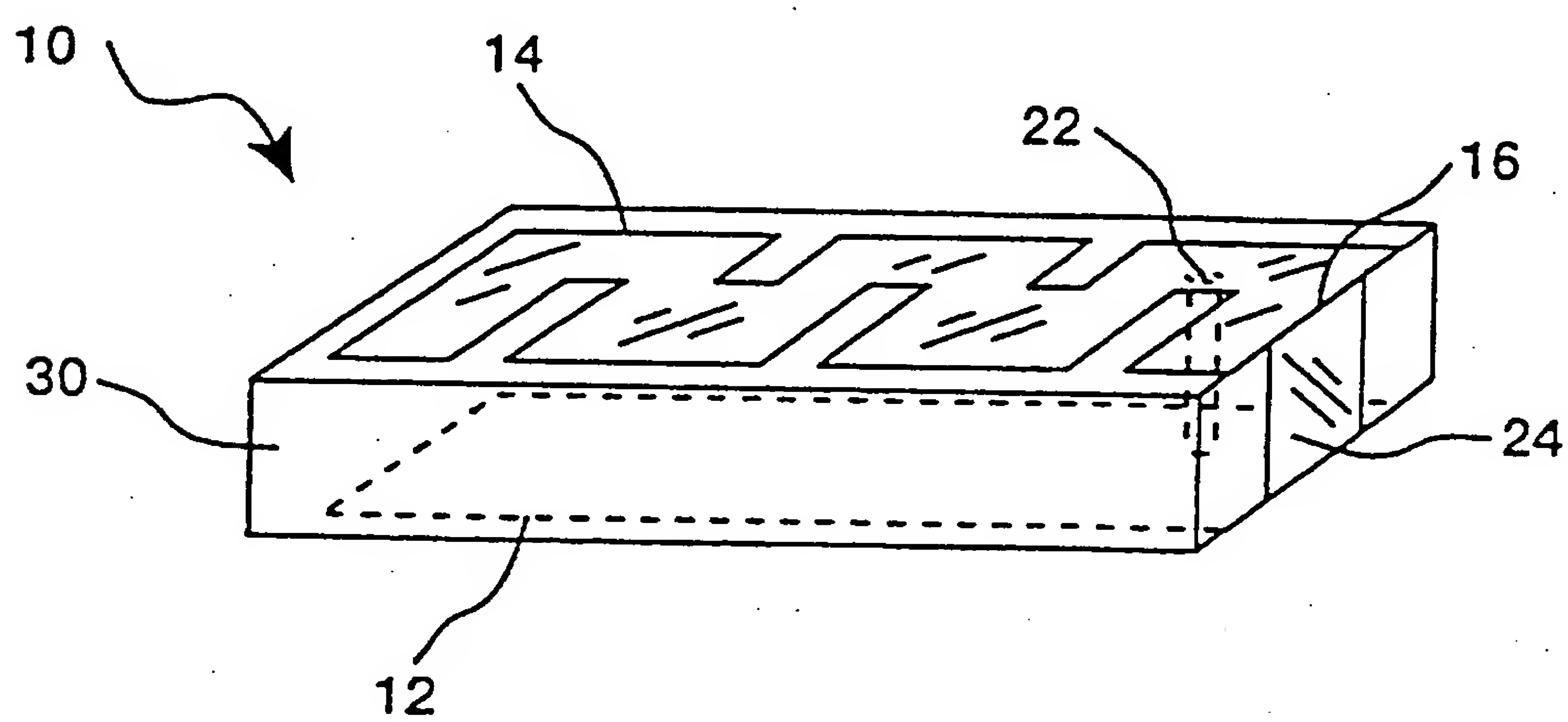

Fig. 2A

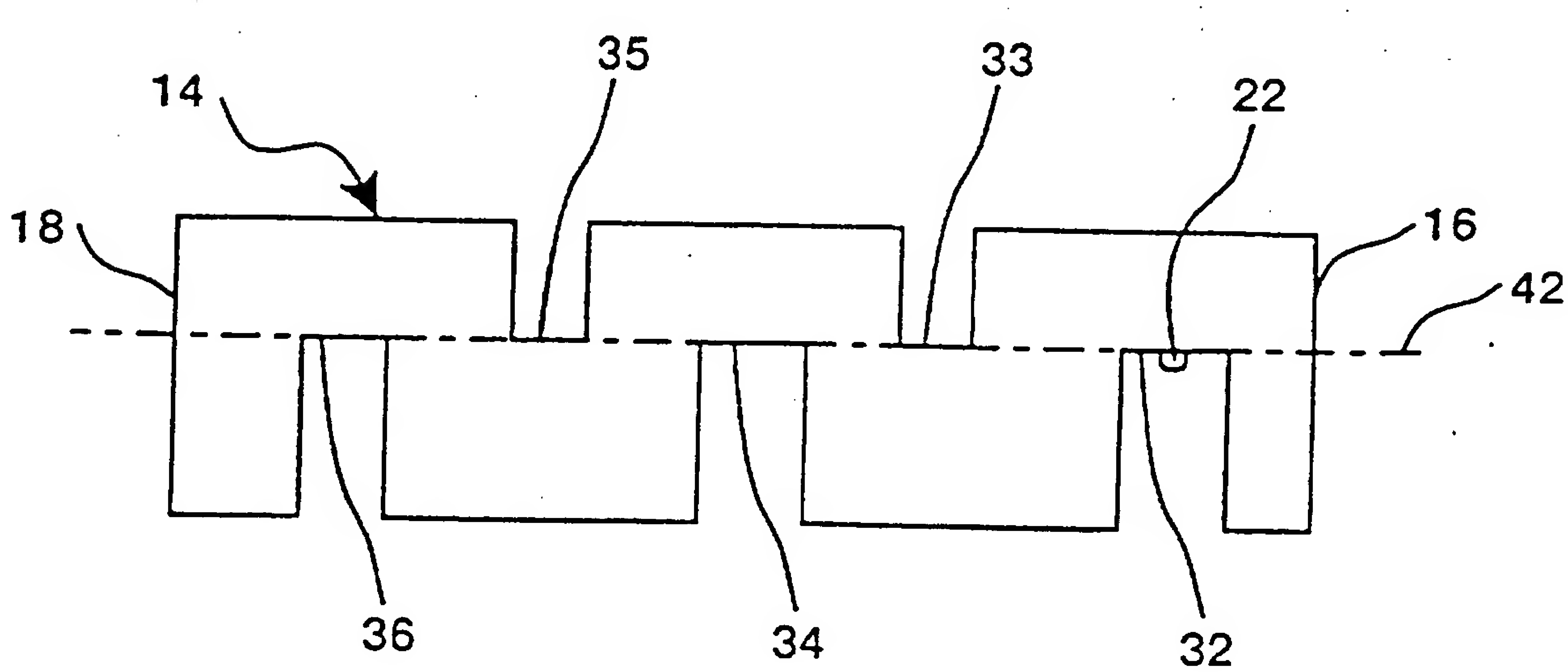

Fig. 2B

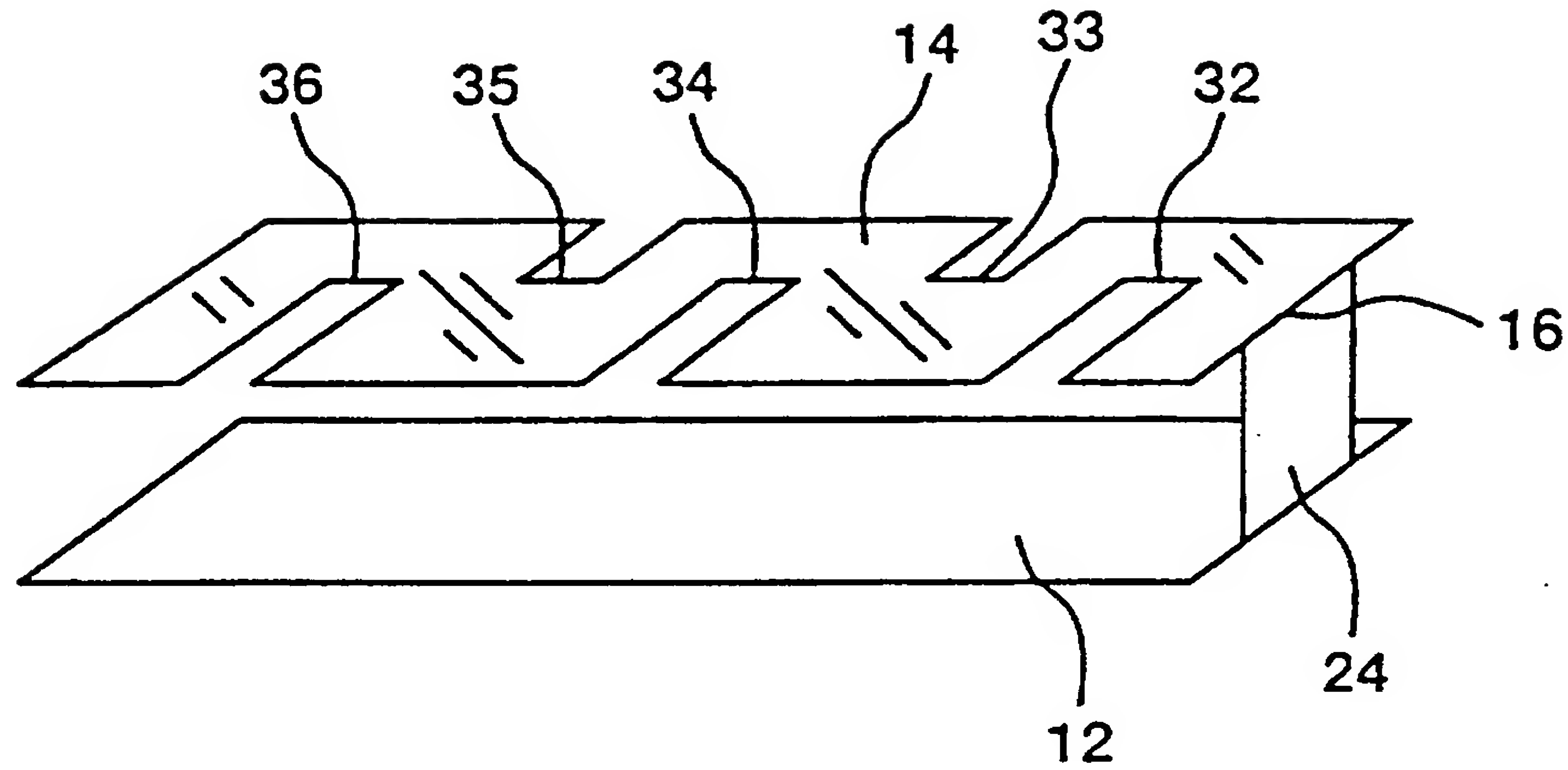

Fig. 3A

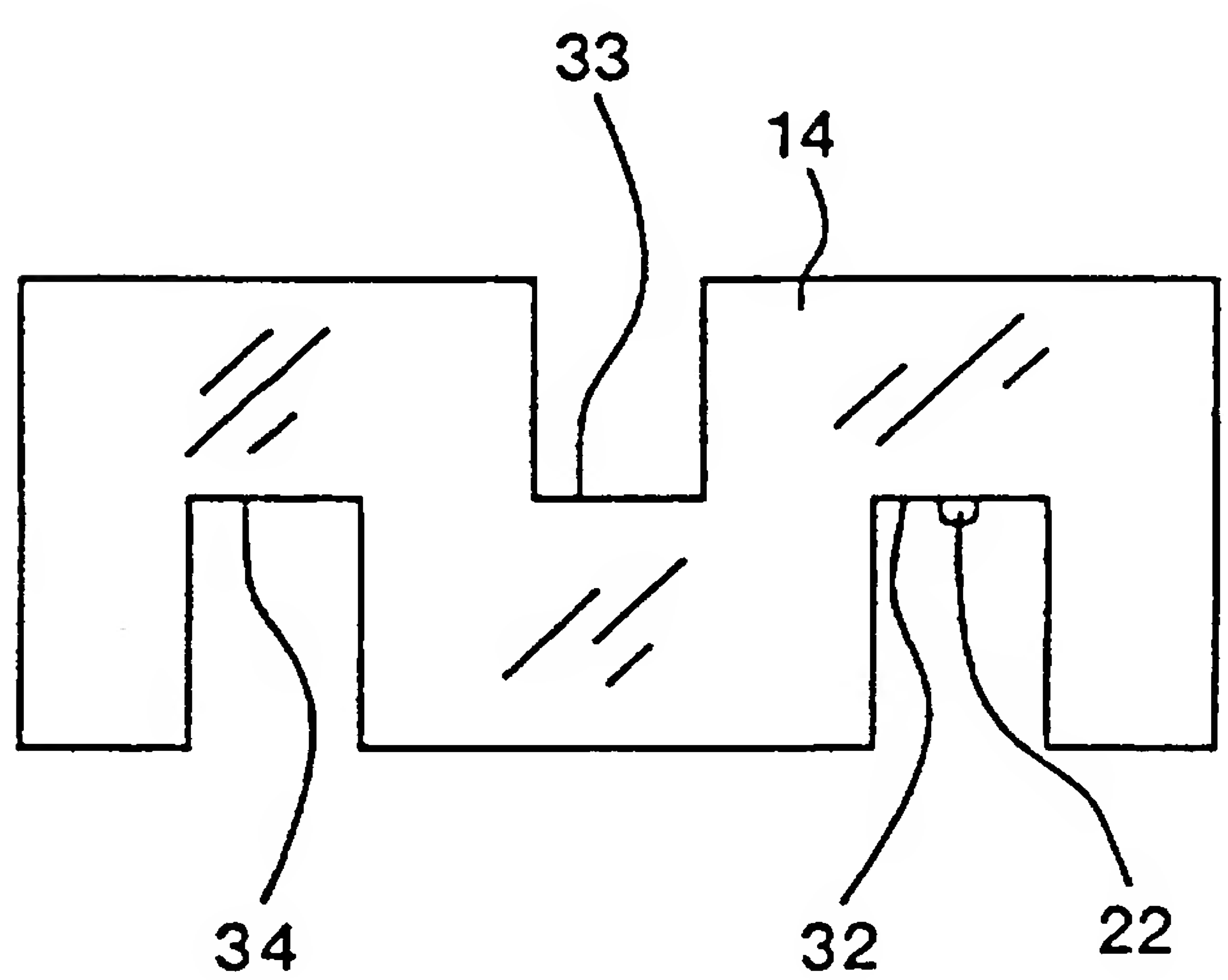

Fig. 3B

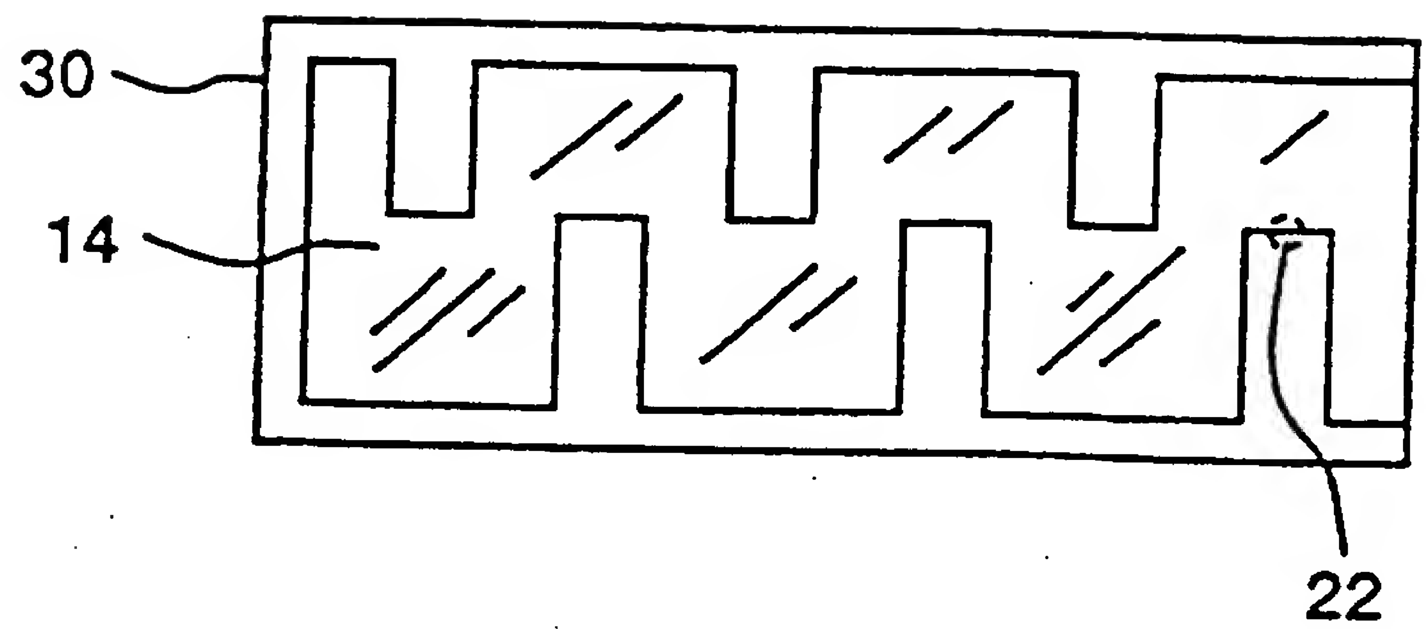

Fig. 4A

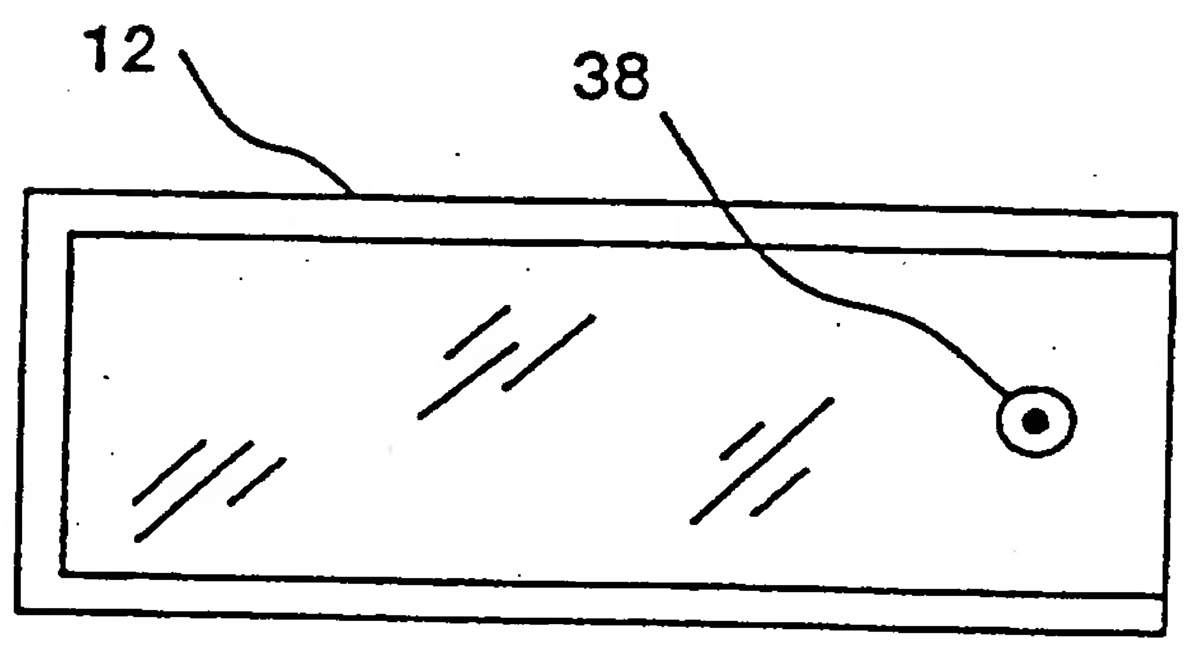

Fig. 4B

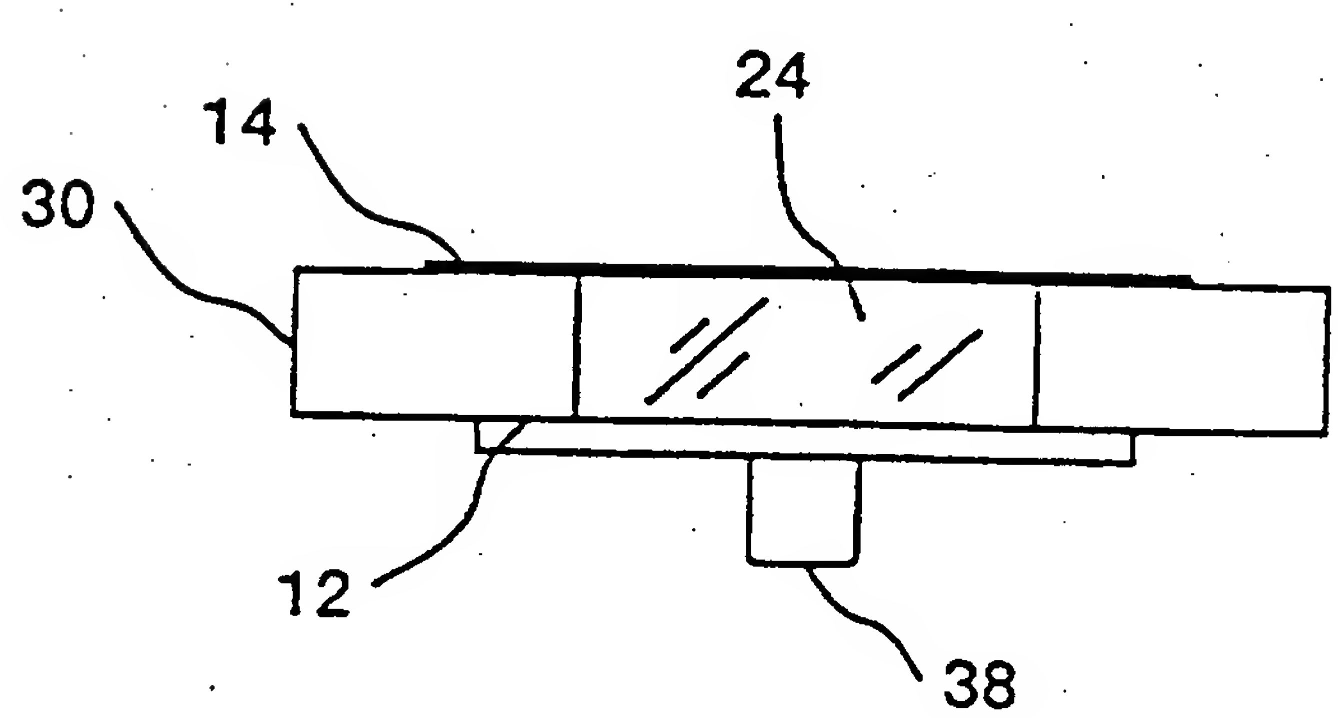

Fig. 4C

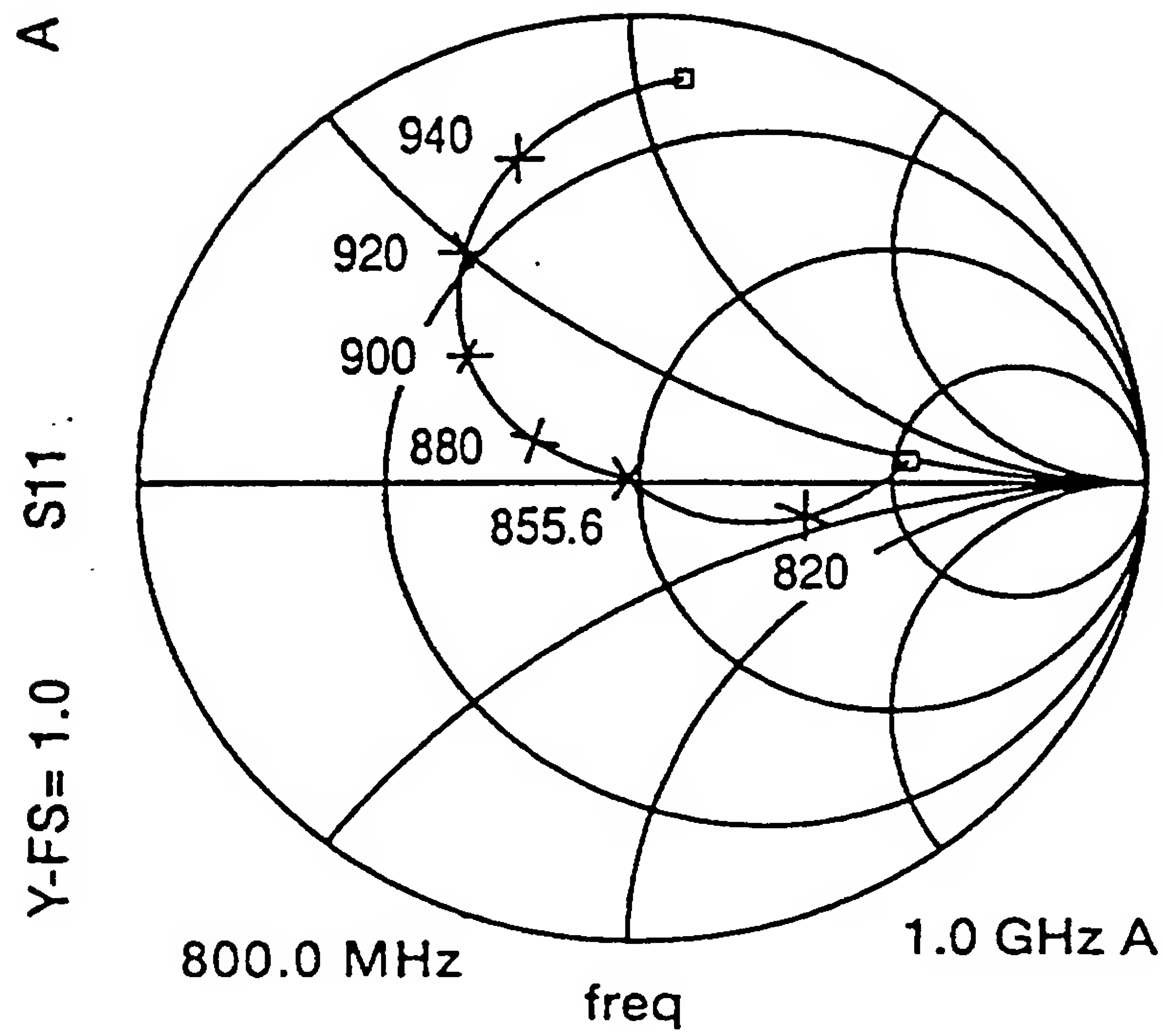
A
S11
Y-FS= 1.0
940
920
900
880
855.6
820
800.0 MHz
freq
1.0 GHz A

Fig. 5A

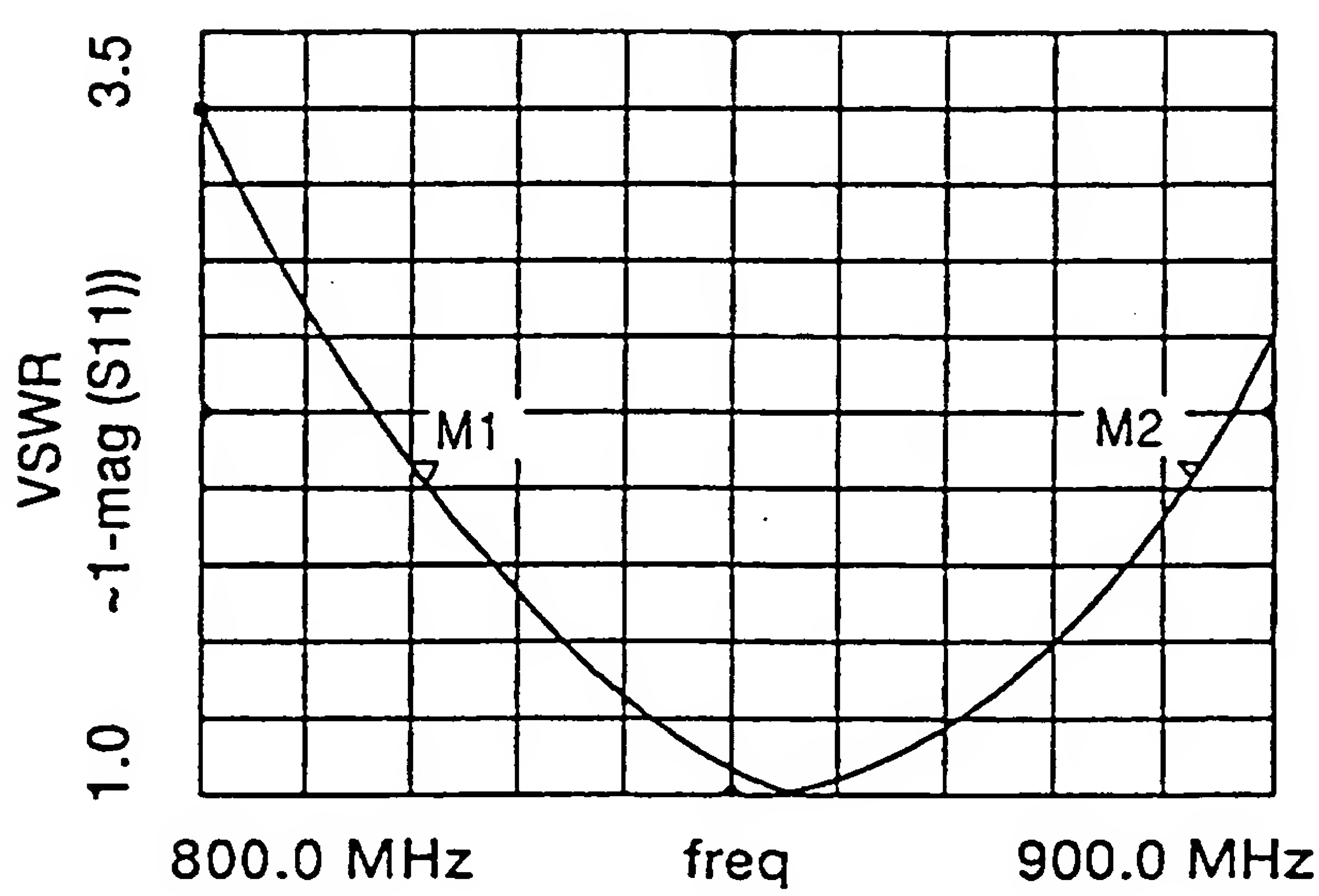
3.5
VSWR
~1-mag (S11))
1.0
M1
M2
800.0 MHz
freq
900.0 MHz

Fig. 5B

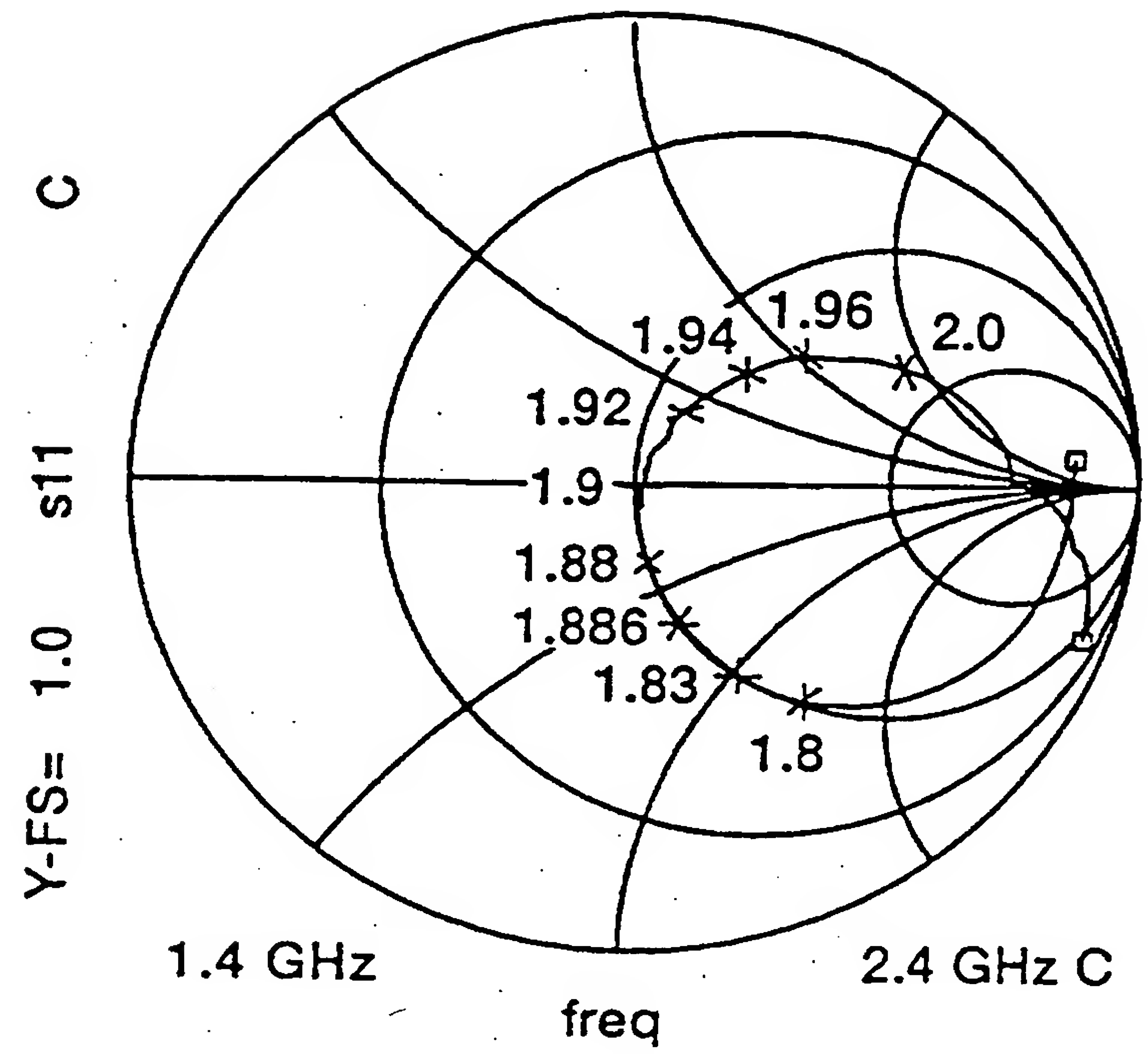
Y-FS= 1.0 s11 C
1.94
1.96
2.0
1.92
1.9
1.88
1.886
1.83
1.8
1.4 GHz
2.4 GHz C
freq

Fig. 6A

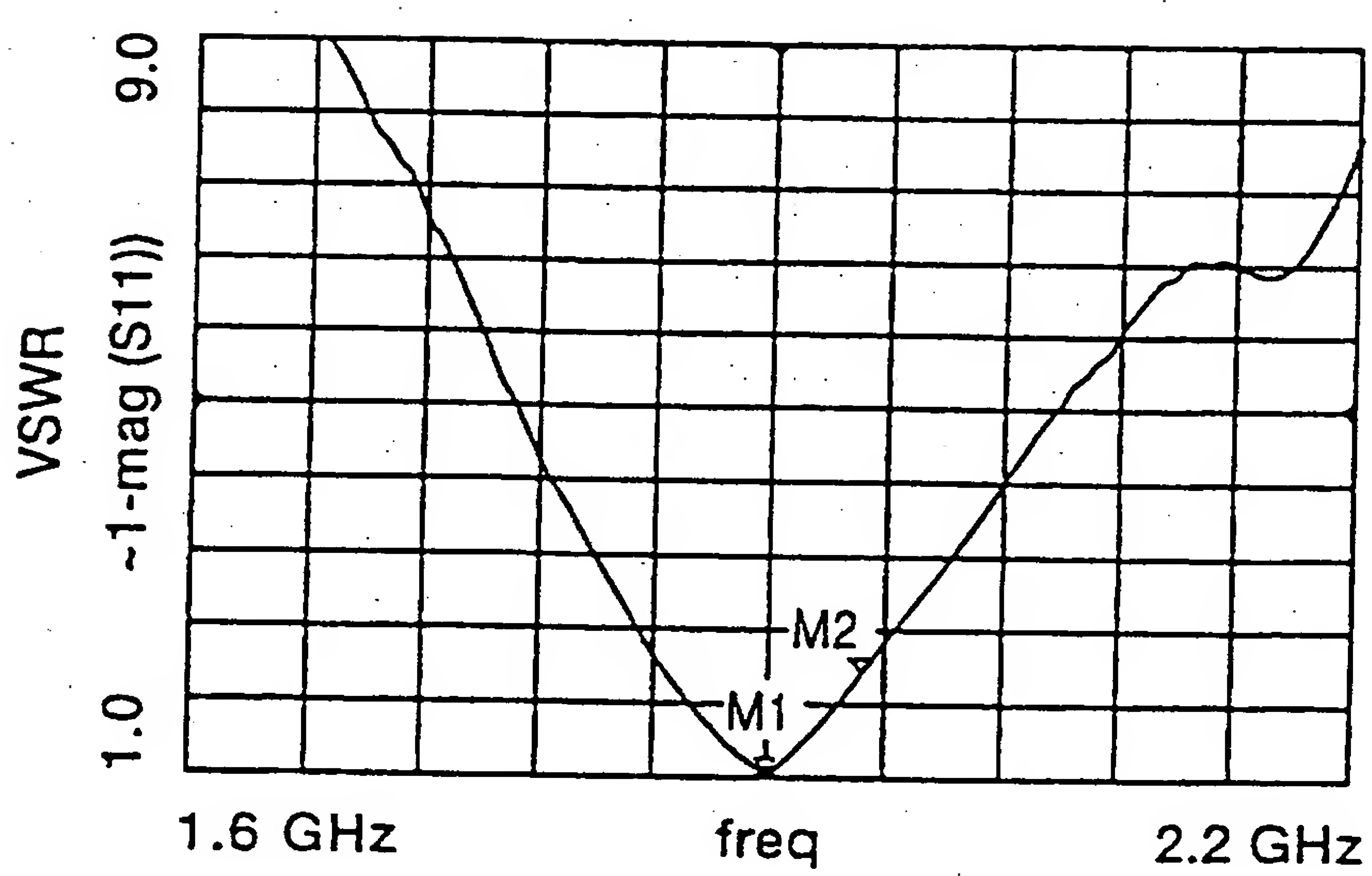
VSWR
~1-mag (S11))
9.0
1.0
M1
M2
1.6 GHz
freq
2.2 GHz

Fig. 6B

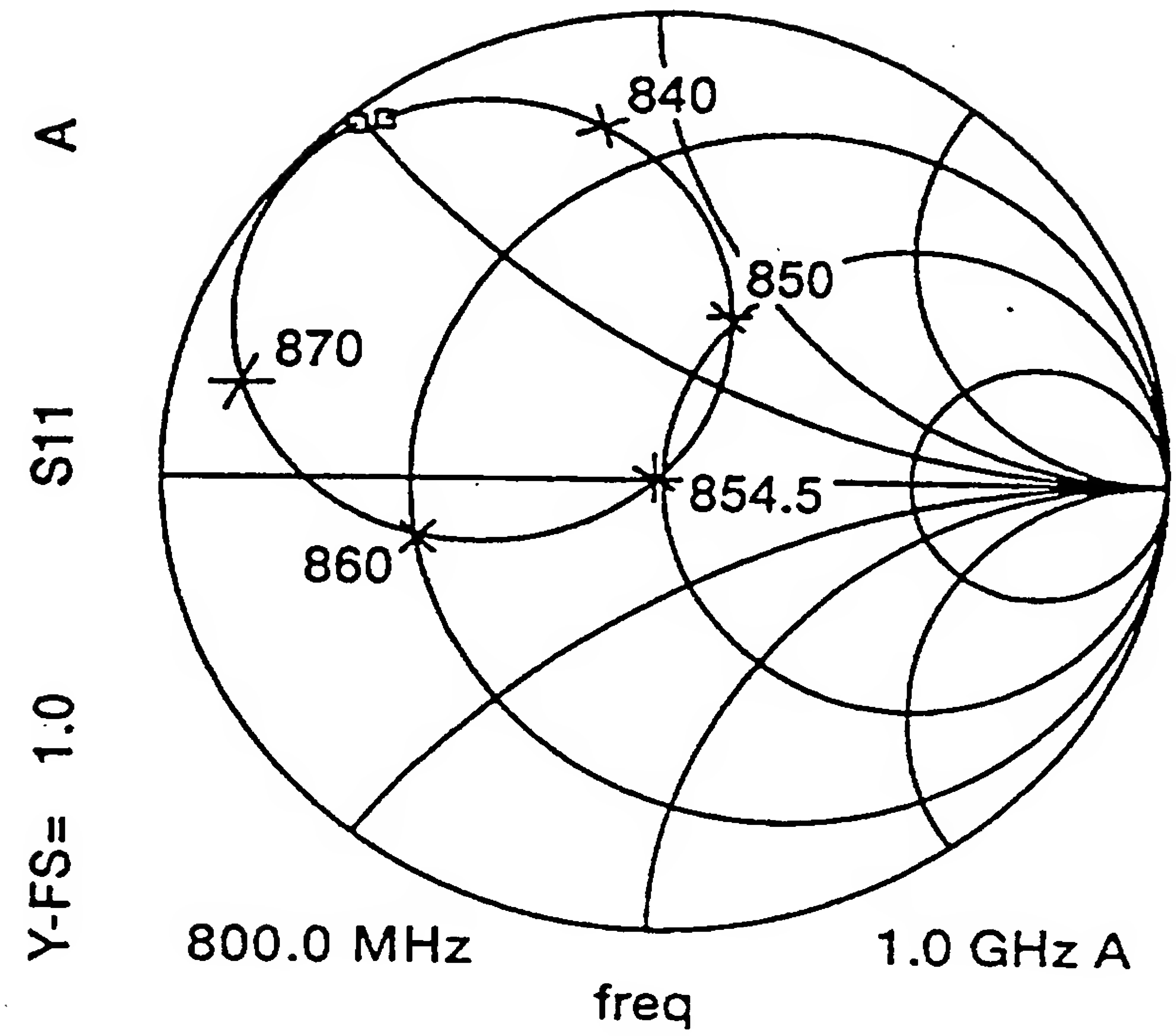
840
850
870
854.5
860
S11 A
Y-FS= 1.0
800.0 MHz
1.0 GHz A
freq

Fig. 7A

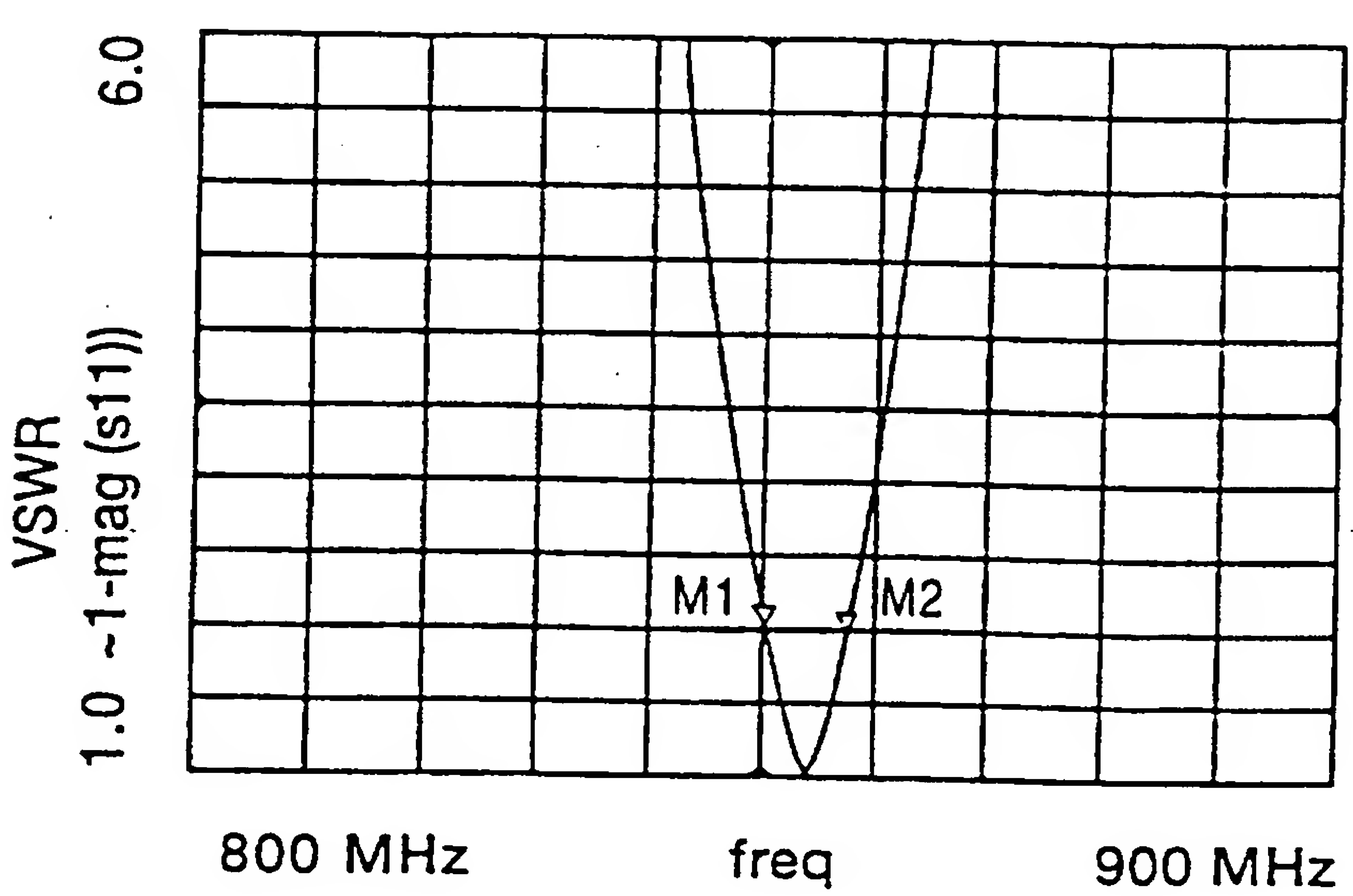
6.0
VSWR
1.0 ~1-mag (s11))
M1
M2
800 MHz
freq
900 MHz

Fig. 7B

INTERNATIONAL SEARCH REPORT

In ational Application No
PCT/GB 96/00285

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01Q9/42 H01Q9/04

According to International Patent Classification (IPC) or to both national classification and IPC

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Minimum documentation searched (classification system followed by classification symbols)
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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO,A,93 12559 (SIEMENS AKTIENGESELLSCHAFT ÖSTERREICH) 24 June 1993 see page 1, line 31 - page 2, line 19	1-3
A	see page 3, line 13 - page 4, line 16; claims 1-7; figure 1 ---	3-11
A	US,A,4 701 763 (YAMAMOTO ET AL.) 20 October 1987 see column 5, line 63 - column 7, line 55; figures 3,9,14 ---	1
A	US,A,4 584 585 (MARKO ET AL.) 22 April 1986 see column 1, line 64 - column 2, line 22; figures 1,2,4 -----	1

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Date of the actual completion of the international search	Date of mailing of the international search report
20 May 1996	13.06.96

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Information on patent family members

International Application No
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Patent document cited in search report	Publication date	Patent family member(s)		Publication date
WO-A-9312559	24-06-93	AT-B-	396532	27-09-93
		AT-T-	126629	15-09-95
		DE-D-	59203316	21-09-95
		EP-A-	0616734	28-09-94
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